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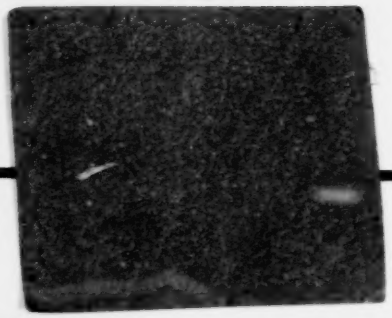

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

REPORT ON THE UNITED NATIONS/INTERNATIONAL ASTRONAUTICAL FEDERATION WORKSHOP ON SPACE TECHNOLOGY AS A COST-EFFECTIVE TOOL TO IMPROVE INFRASTRUCTURES IN DEVELOPING COUNTRIES

(Turin, Italy, 2-5 October 1997)

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INTRODUCTION

A. Background and objectives

1. The General Assembly, in its resolution 37/90 of 10 December 1982, decided that, in accordance with the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space,[1] the United Nations Programme on Space Applications should assist the developing countries in establishing an autonomous technological base for the development and use of space technology by promoting the growth of indigenous capabilities. The Committee on the Peaceful Uses of Outer Space at its thirty-ninth session took note of the activities of the United Nations Programme on Space Applications for 1997, recommended by the Scientific and Technical Subcommittee at its thirty-fourth session.[2] Subsequently, the General Assembly, in its resolution 51/123 of 13 December 1996, endorsed the activities of the Programme for 1997.

2. The present report contains a summary of the United Nations/International Astronautical Federation Workshop on Space Technology as a Cost-effective Tool to Improve Infrastructures in Developing Countries. The Workshop was organized as part of the 1997 activities of the Office for Outer Space Affairs of the United Nations Secretariat under the United Nations Programme on Space Applications. The Workshop was the seventh in a series organized by the United Nations, and was held at Turin, in conjunction with the forty-eighth Congress of the International Astronautical Federation (IAF). Previous symposia and workshops in the series had been held in Austria, Canada, China, Israel, Norway and the United States of America.

3. The objectives of the Workshop were to assist developing countries in establishing and strengthening national capabilities in space technologies and applications, to provide developing countries with a general plan for establishing cost-effective industrial and institutional enterprises in selected fields of space science and technology, to explore the possibility of an increased scientific and technical cooperation between industrialized and developing countries, as well as between the developing countries themselves; and to explore the possibility of cooperative ventures involving space industry and developing countries. The Workshop was intended to provide a forum for interaction with representatives of the space industry, thereby helping the participants to gain a greater understanding of the needs and requirements that should be met if ventures were to be successful. The observations of participants and the conclusions reached by the Workshop would also provide inputs and ideas to the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, which will be held at Vienna from 19 to 30 July 1999.

4. The sponsors of the Workshop were able to provide participants from developing countries with the opportunity to attend the technical sessions associated with the forty-eighth Congress of IAF, which began immediately after the Workshop. That had become one of the objectives of the series of workshops, as it allowed participants from developing countries to present papers and hold discussions with their colleagues in one of the more important international space events.

5. This report, covering the background and the objectives of the Workshop, as well as the presentations and discussions, and the observations made and conclusions reached by the participants, has been prepared for consideration by the Committee on the Peaceful Uses of Outer Space at its forty-first session and by its Scientific and Technical Subcommittee at its thirty-fifth session. The participants will report to the appropriate authorities in their own countries. The proceedings of the Workshop, including a detailed address list of all participants, will be made available through the Office for Outer Space Affairs in due time.

B. Programme of the Workshop

6. During the course of the Workshop, successful examples for the use of space technology applications were presented. The aim was to demonstrate how developing countries could benefit from space technology for economic and social development. The Workshop was structured around six sessions, in which 23 papers were presented. There was a vigorous exchange of information, comments, questions, recommendations and suggestions. In addition, the brief presentations by participants from developing countries provided an insight into the status of space technology applications in their countries. Afternoon sessions concluded with panel discussions, followed by an open exchange of views.

7. National and transnational space projects and programmes were discussed, and possibilities were suggested for increased scientific and technical cooperation between industrialized and developing countries, as well as among the developing countries themselves.

C. Participants

8. The United Nations invited developing countries to nominate candidates for participation in the Workshop. Selected participants were required to have university degrees in remote sensing, communications, engineering, physics, biological or medical sciences or other fields related to the themes of the Workshop. In addition, participants were selected on the basis of their working experience in programmes, projects or enterprises in which space technology is or could be used. The participation of policy makers at a decision-making level from both national and international entities was specifically encouraged.

9. Funds allocated by the United Nations, IAF, the European Commission, the European Space Agency (ESA) and the Government of Italy for the organization of the Workshop were used to cover international air travel and per diem expenses of 30 participants from developing countries. Registration fees for the Congress and room and board expenses for participants from developing countries were also covered by the sponsors of the Workshop.

10. The Workshop was attended by more than 120 participants, including funded participants from Azerbaijan, Bangladesh, Benin, Brazil, Burkina Faso, China, Ethiopia, India, Indonesia, Iran, Jordan, Malaysia, Nicaragua, Nigeria, Pakistan, Sri Lanka, St. Lucia, Sudan, the United Republic of Tanzania, Uzbekistan, Venezuela and Zimbabwe.

11. Lectures were delivered by representatives of the Office for Outer Space Affairs, the World Meteorological Organization (WMO), the European Commission, ESA, the Austrian Space Agency, the Chinese Academy of Space Technology, the French National Centre for Space Studies, the German Aerospace Research Establishment, the Indian Space Research Organization, the Italian Space Agency, the National Aerospace Laboratory of the Netherlands, the National Space Development Administration of Japan, the Space and Upper Atmosphere Research Commission of Pakistan (SUPARCO) and the International Space University.

12. Presentations by space industry and commercial ventures were given by representatives of CLS-ARGOS (France), Earth Observation Satellite Company (EOSAT) (United States), ORBCOMM (United States), ORBIMAGE (United States), SPACEHAB (United States) and Surrey Satellite Technology Ltd. (United Kingdom of Great Britain and Northern Ireland).

I. PRESENTATIONS AND DISCUSSIONS

13. Opening statements were made by the Head of the Italian Space Agency, a member of the Indian Space Commission and Honorary Chairman of the Committee for Liaison with International Organizations and Developing Nations of IAF, the representative of ESA, the President of IAF and the Director of the Office for Outer Space Affairs, as well as by representatives of the City of Turin and the International Training Centre of the International Labour Organization (ILO).

14. The cost-effectiveness of space technology applications as an alternative for developing countries was illustrated by the representative of the Chinese Academy of Space Technology in his keynote address on space technology applications, the cost-effective alternative for developing countries. Major examples of successful space technology applications in China included satellite-telecommunications, tele-education and Earth observation projects covering meteorological forecasting, natural disaster mitigation and resources management. One of the biggest challenges for China, which had a land area of 96 million square kilometres and a coastal area of 3 million square kilometres, was the unbalanced development and underdeveloped infrastructure, especially in its rural regions. Space technology applications provided a low-cost and high-benefit solution for many of those problems, improving the economic, social and cultural development of the country. In the near future, China would have an enormous market potential for satellite direct television broadcasting, satellite mobile communication and satellite direct radio broadcasting. China had also started to use retrievable space platforms for rice and wheat breeding experiments in the micro-gravity environment of space. Farmers benefited through a higher yield from the new crop seeds.

15. The representative of the Italian Space Agency, speaking on space technology for infrastructure improvement in developing countries, stressed that space data needed to be integrated with other collateral data to provide useful information for infrastructural development and management that could be directly interpreted by policy makers and decision makers.

A. Enhancing the cost-effectiveness of space technology applications

16. ESA had analysed and quantified the direct benefits of some of its major programmes, including the METEOSAT satellites, the Ariane launcher and the European Communication Satellite (ECS). In addition to the direct benefits, indirect effects needed to be considered. A study had revealed that for every currency unit invested by ESA, more than three currency units were generated in indirect economic activities. Further indirect benefits to be considered were of a technological, commercial, organizational and educational nature. It was, however, rather difficult to quantify benefits before the programmes had been implemented. The commercial success of the Ariane and ECS programmes had not originally been foreseen. It was, however, becoming easier to predict the cost of space projects as more and more sophisticated cost-analysis tools were being developed. Those in turn could be very useful for trading options, benchmarking proposals or giving realistic estimates of the resources needed by a project.

17. With the growing demand for resources, due, for example, to increasing population pressure, it was necessary to improve methods for resource management without adversely affecting the environment. The means for achieving that balance was known as sustainable development. Space technology applications could provide significant support for the sustainable development of a country. The representative of the National Remote Sensing Agency of India gave a brief account of the Indian space programme, followed by a detailed description of example applications, using remote sensing data and Geographical Information Systems (GIS) in an integrated approach to the identification of land use alternatives for sustainable land and water management in a selected watershed of the Ahmednager district of Maharastra. Using space technology, the generation of local action-plan maps cost half as much as it did using conventional methods (2.43 rupees per hectare as against 5.10 rupees per hectare (36 rupees equalling approximately 1 United States dollar ($)). Cost

was calculated using data obtained between 1993 and 1994 from extensive studies covering large areas and representing different terrains.

18. The European Commission, as the largest buyer of remote sensing data in Europe, was an important player in the operationalization of Earth observation programmes. As part of its activities, the European Commission was also offering education and training programmes for developing countries. Courses in remote sensing were offered for two weeks in the year by the Joint Research Centre, in collaboration with International Centre for Agronomic Studies, Spain, or on a case-by-case basis in the frame of projects financed under the following programmes: Tropical Ecosystem Environment Observations by Satellite (TREES), Fire in Global Resource and Environmental Monitoring (FIRE), Satellite Assessment of Rice in Indonesia (SARI), South East Asia Rice Radar Investigation (SEARRI), Ecosystem of Forest in Central Africa (ECOFAC) and others.

B. Space technology: a cost-effective tool for developing countries

19. The broad range of benefits that space technology applications could provide to developing countries was evident in the presentation on the review of follow-up activities of previous United Nations/International Astronautical Federation workshops. For the review, the Office for Outer Space Affairs had contacted 152 former participants in United Nations/International Astronautical Federation workshops and asked them to provide information on their follow-up activities. The former participants had also expressed their views on the usefulness of the workshops. Among other things, the respondents indicated that the workshops provided an excellent opportunity for a general exchange of information on space technology applications and for networking with colleagues from other countries.

20. Environmental monitoring had long been recognized as an important application of space technology, with its ability to provide the holistic view necessary for effectively tackling and solving problems. Examples were given by the participant representing SUPARCO, Pakistan, in his presentation on the role of space technology in creating environmental awareness. Satellite data were frequently being used for the monitoring of river course changes, mapping of floods and areas affected by salinization, prospecting for oil field studies and measuring the ozone depletion in the atmosphere. It was often forgotten that low-resolution data provided the most cost-effective approach for such large-area studies.

C. Operationalization of remote sensing applications

21. The representative of the Remote Sensing Exploitation Department of ESA presented an overview of the remote sensing data market. He outlined the main steps involved in making remote sensing applications operational: research, demonstration, pre-operations and operations. Only a few systems, mostly those providing meteorological data, were currently operational. That situation was expected to change soon with the advent of commercial remote sensing satellites. Some applications, including applications in research, geology, environment, agriculture, mineral prospecting, and oil-spill detection, were already mature, while others, like applications covering GIS simulations, insurance, shipping and engineering, were developing at different rates.

22. The current market value of remote sensing data was $200 million a year for data providers and some $300 million to $500 million a year for value-added companies, with an expected annual increase rate of 15-20 per cent. Remote sensing data per se had little commercial value. It was rather the information that the data could provide, and the resulting services, that would determine the commercial impact of the remote sensing market.

23. When considering the cost-effectiveness of space image data, a direct comparison with aerial photography revealed that surveying with remote sensing data was cheaper when the surveyed area was larger than 20 square kilometres. Earth observation from satellites would for the first time come into direct competition with aerial

photography early in 1998, when the first civilian remote sensing satellites providing a similar spatial resolution would be launched.

24. An example of a future operational Earth observation system was the VEGETATION payload, which would be launched with the SPOT-4 satellite. The payload had been developed jointly by France, Belgium, Italy, Sweden and the European Commission, and would tentatively be launched in March 1998. It would deliver measurements with a medium spatial resolution of one kilometre, specifically tailored to land-surface monitoring parameters, with an approximately once-daily revisiting frequency on a global basis. The system would complement the existing spatial high-resolution capabilities of the SPOT satellite series, providing simultaneous spectral measurements in the visible and short-wave infrared domain of the electromagnetic spectrum. Applications in agriculture, forestry and environmental monitoring were being prepared. Further information on the VEGETATION payload was available at <http://www-vegetation.cst.cnes.fr:8050/>.

25. The coastal environment functioned as a buffer zone and interface between land and the open oceans and required heavily integrated coastal zone management to achieve sustainable development. The coastal zone comprised 18 per cent of the global surface, housing approximately 60 per cent of the human population and accounting for 90 per cent of the world's fish catch. The Marine Environment Unit in the Space Applications Institute of the Joint Research Centre of the European Commission used space technology to monitor toxic algae blooms in the Baltic and to give early warning of the "white tide" in the Northern Adriatic sea. A number of Ocean Colour Sensors were used or were being developed for oceanographic studies (for example, the Global Imager (GLI) and the polarization and directionality of the Earth's reflectances sensor (POLDER) on ADEOS II, the Sea Wide-Field Sensor (SeaWiFS) on OrbView-2, the Moderate Resolution Imaging Spectroradiometer (MODIS) on EOS AM-1 and EOS PM-1, the Medium Resolution Imaging Spectrometer (MERIS) on ENVISAT 1) and high-resolution sensors were used for coastal change studies (for example, the Advanced Visible and Near Infrared Radiometer (AVNIR) on ALOS, the Thematic Mapper (TM) on Landsat 5, the High Resolution Visible (HRV) on SPOT 1 and SPOT 2, the Modular Optoelectronic Multispectral Scanner (MOMS) on Priroda (MIR Space Station)). Earth observation of coastal regions were still in a pre-operational stage, key constraints being the lack of continuously operational Ocean Colour Sensors, lack of appropriate algorithms with local and timely calibration, low frequency of measurements, difficult access to data, unfriendly integration scheme with other data sources and poor information dissemination. Those problems were being tackled by several institutions with a view to creating a system to integrate multiple data sources and to assimilate data over time to improve the information on coastal regions.

26. The Director of the Andhra Pradesh State Remote Sensing Application Centre in India demonstrated the potential of remote sensing data and GIS for the management of natural resources at the village level. Mapping of geomorphology, lithology, geology, structure and lineaments, land use and land cover, soils, slopes, surface water bodies, drainage and watersheds, transportation networks, settlement locations and village boundaries had been completed on a 1:50,000 scale, using both remote sensing and conventional data. The acquired information had resulted in specific local recommendations for the rainwater harvesting structure, soil moisture conservation and fodder and fuel wood development.

D. Benefits of international cooperation in space activities

27. The representative of the National Aerospace Laboratory of the Netherlands presented the Forest Assessment and Monitoring Environment (FAME) concept for a worldwide operational forest monitoring system. Studies by the Food and Agriculture Organization of the United Nations (FAO) had revealed several impediments to the operational use of remote sensing satellites and GIS for sustainable forest management. They included political and financial factors and also functional and performance requirements. The FAME concept was intended to overcome those limitations, enabling the forest manager to acquire information on

forest changes directly where it was needed, in the office of the forest manager. Information on the latest FAME developments could be requested from <fame@itc.nl>.

28. Remote sensing cooperation activities in the Asia and the Pacific region of the National Space Development Agency (NASDA) of Japan were discussed by a representative of its Office of Earth Observation. NASDA had launched several Earth observation satellites, including the Marine Observation Satellites MOS-1 and MOS-1b, the Japanese Earth Resources Satellite JERS-1, the Advanced Earth Observing Satellite ADEOS (no longer functional), the Tropical Rainfall Measuring Mission TRMM, and several geostationary meteorological satellites. ADEOS-II and the Advanced Land Observing Satellite ALOS were currently at the development stage. Bilateral cooperation projects with countries in the Asia and the Pacific region included direct data reception of JERS-1 in Australia, Canada, China, Indonesia, the Republic of Korea, Thailand and the United States. Pilot projects for practical data use had been established with Thailand, including data analysis cooperation in the Global Energy and Water Cycle Experiment (GEWEX). Several multilateral cooperation projects had been started and others were under consideration.

29. The representative of the Scientific and Industrial Research and Development Centre of Zimbabwe discussed his country's experiences with space systems for disaster warning in Southern Africa. While remote sensing applications for mining and forestry had already been established, the problem of drought mitigation was still not being properly dealt with. He also discussed the influence of the 1997 El Niño phenomenon, which had caused drought in certain parts of Zimbabwe, and the need to use space technology to mitigate the effects of such disasters.

30. The Director of the World Weather Watch programme of WMO made a presentation on the topic "Meteorology in the year 2000: the impact of remote sensing". General improvements in space-based meteorology beyond 2000 would include better detection of natural hazards, increased use of applications, improved timeliness and accuracy of forecasts and warnings and enhanced capabilities to distribute meteorological information among nations and to the public. That would lead to improved aviation and marine and maritime safety and efficiency, agricultural productivity, forest and range management, weather forecasting for the public, environmental quality and understanding of the climatology and climate variability.

E. Presentations by representatives of the space industry

31. Surrey Satellite Technology Ltd. was well known for its development of a series of small satellites (100-500 kg class) that could provide developing countries with affordable access to space. Technology transfer programmes had taken place with Chile, Malaysia, the Republic of Korea, Pakistan, Portugal, Singapore, South Africa and Thailand. The objectives of the programmes were to train engineers to be the nucleus of an indigenous space industry, to launch a first national microsatellite and demonstrate its applications and to establish national space facilities and capabilities. The technology transfer programmes covered microsatellites and ground stations and involved both academic and skill training. Current studies for future projects included a microsatellite constellation for disaster monitoring from space and a low Earth equatorial orbit constellation of telecommunications satellites, as well as a possible scientific lunar mission that would require international cooperation.

32. Argos was a global satellite-based location and data collection system that had been operational since 1978; it was dedicated to studying and protecting the environment. Currently, two polar-orbiting National Oceanic and Atmospheric Administration (NOAA) satellites were used to receive and retransmit signals for various applications, including the monitoring of fishing vessels, wildlife studies, oceanography, volcanology, hydrology, glaciology and meteorology. The time from acquisition to delivery of data could be as little as 20 minutes. Thousands of water, land and airborne transmitters weighing under 1 kg and as little as 25 g were currently in operation. An enhanced Argos-2 payload would be launched on-board NOAA-K in early 1998 and

on the future NOAA Polar Orbiting Environmental Satellite System (POESS). In 1999, an Argos-2 instrument, with downlink messaging capability, would be put into orbit with ADEOS-II and later Argos-3 would be launched with the European METOP-1 satellite.

33. ORBCOMM was the world's first commercial low-Earth orbit (LEO) mobile satellite system providing global two-way narrow-band data communication. The first two satellites were in orbit and the full constellation of 28 satellites would be in service in 1998. The technology was based on low-cost LEO satellites and low-cost subscriber equipment, providing a cost-effective solution for applications, including data monitoring, tracking of transportation and heavy equipment, environmental data collection and messaging.

34. ORBIMAGE had successfully launched the OrbView-1 and OrbView-2 satellites. OrbView-1 was the world's first privately operated weather satellite, mainly providing scientific and environmental data with a low spatial resolution of 10 kilometres and a high temporal resolution for disaster detection capability. OrbView-2 was an operational satellite providing daily colour images of the world with 1.1 kilometres spatial resolution. Its major commercial applications included coastal zone and environmental monitoring, marine navigation, offshore oil and gas operation, natural disaster mitigation and coastal and deep ocean fishing. OrbView-3 would provide 1 and 2 metre resolution in panchromatic mode, 4 metre resolution in multispectral mode, and 8 metre resolution in hyperspectral mode (280 bands) imaging, and would complement the capabilities of the existing satellites.

35. Space Imaging EOSAT had integrated the world's largest constellation of satellites and aerial mapping sources, including the Landsat satellites, the Indian Remote Sensing (IRS) satellites, the Canadian RADARSAT satellite, the Japanese Earth Resources Satellite (JERS-1) and the ESA ERS-1 and ERS-2 satellites. Imagery with 1 metre high-resolution in panchromatic mode and 4 metre resolution in multispectral mode would be provided by IKONOS 1, to be launched early in 1998.

36. The President of the Association tunisienne de la communication emphasized in his presentation on education at a distance the benefits of using space technology for distance education. Merging the capabilities of telecommunications satellites with the interactivity provided by the Internet offered new prospects for tele-education applications, which would be particularly important in providing those services to regions with an underdeveloped infrastructure.

F. Space spin-offs and future applications

37. The International Space University (ISU) was a non-profit educational institution specializing in multidisciplinary advanced space study programmes. One of the two projects developed during the 1997 ISU summer session programme at Houston, Texas, focused on technology transfer. Specific coverage was given to methods for improving the transfer of technologies between the space and non-space sectors. The executive summary and the full report could be ordered from <publications@isu.isunet.edu>.

38. The Institute of Aerospace Medicine of the German Aerospace Research Establishment was conducting a number of telemedicine projects. Argonauta was a project to set up regional health-care networks in Argentina and Chile with links to German and Italian medical centres using mobile equipment and satellite technology. The remaining challenge, however, was to integrate developing countries into the Global Information Society.

39. With the imminent start of construction of the International Space Station in 1998, human spaceflight had become the prime domain for international cooperation in space. Although most developing countries had rightly set their top priorities in the fields of telecommunications and remote sensing applications, a few developing countries were considering or had already taken first steps to participate in human spaceflight missions. Once a country had decided to fly payloads on human-tended platforms, the challenge was to find

adequate flight opportunities. SPACEHAB provided commercial beginning-to-end services for private and governmental customers. Possible applications of interest to developing countries included microgravity and life science research, chemical and biological processing and material research.

II. OBSERVATIONS AND CONCLUSION

40. Considering that the cost-effectiveness of space technology applications had been demonstrated in several application domains for improving infrastructures, the participants observed that specific and focused cooperative efforts should be made by international organizations and by national entities to promote the use of appropriate technologies. That would reduce the risk that the lack of national resources in developing countries would lead to a discriminatory situation in which space technology could not be used to help the development of those countries.

41. To trigger long-term sustainable development and to support the building of indigenous capacities in developing countries, international cooperation had to materialize in the form of:

(a) The effective transfer of know-how to developing countries through education, on-the-job training, opportunities to attend meetings, networking capabilities and access to information;

(b) Coordinated and targeted funding of application projects of high relevance to developing countries, based on a committed partnership by the developing countries in terms of human, technical and financial resources;

(c) The provision of business opportunities for local industry through joint ventures with companies from more developed countries.

42. International organizations were urged to play a key role in ensuring that the above measures were implemented as quickly and as widely as possible, while Governments of developing countries were urged to consider the use of space technology as a cost-effective tool to improve infrastructures and consequently to commit human and financial resources to implementing its use in the country.

43. The creation of an international advisory body on space technology was urged, whose main task would be to act as a reference contact entity for institutions in developing countries that were willing to improve the national use of space technology. That body should, among other things:

(a) Ensure the availability of simple but effective executive brochures on the cost-benefit results that could be expected from application projects;

(b) Provide developing countries with dedicated, integrated and easy-to-access information on results achieved through the use of space technology, sources of specific information, and opportunities to attend events and meetings;

(c) Help institutions from developing countries to define their specific needs for cost-benefit analyses of using space technology in local application activities;

(d) Advise institutions from developing countries on how to prepare space technology application projects to attract international cooperation and funding opportunities.

44. Participants also reiterated many problems that had already surfaced during the discussions in previous workshops, in particular the following:

(a) There were already a number of applications, for example forestry, land use and land cover, geology and agriculture monitoring, that were close to operational maturity. Availability, the standardization of data sets and in many cases also the affordability of space technology were, however, matters of great concern, especially for the developing countries that would benefit most from those applications;

(b) Among key issues preventing the use of space technology in developing countries were the lack of training opportunities, the low number of skilled personnel and a weak or non-existent basic support infrastructure. The needs of developing countries should therefore be defined, bearing in mind their existing resources;

(c) There was an urgent need to make decision makers more aware of the capabilities of space technology applications and their utility in developing infrastructure and of the cooperative effort programmes already in existence which were designed to achieve sustainable development.

45. The participants concluded that the use of space technology for the mapping of natural resources had proved to be cost-effective, especially with regard to improving infrastructural facilities in some developing countries. The lack of national resources should not therefore be considered as an insurmountable barrier for the use of space technology in solving problems, as the resulting benefits would outweigh the initial burden of investing in space technology for monitoring natural resources and improving infrastructural facilities.

Notes

[1]See *Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-21 August 1982* (A/CONF.101/10 and Corr.1 and 2), part one, sect. III.F, para. 430.

[2]*Official Records of the General Assembly, Fifty-first Session, Supplement No. 20* (A/51/20), sect. II.B, para. 39.

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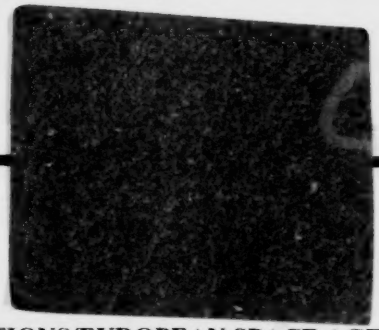

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

REPORT ON THE UNITED NATIONS/EUROPEAN SPACE AGENCY/COMMITTEE ON SPACE RESEARCH WORKSHOP ON DATA ANALYSIS TECHNIQUES, HOSTED BY THE BRAZILIAN NATIONAL INSTITUTE FOR SPACE RESEARCH ON BEHALF OF THE GOVERNMENT OF BRAZIL

(São José dos Campos, Brazil, 10-14 November 1997)

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EXPLANATORY LIST OF TECHNICAL TERMS AND ABBREVIATIONS

2D	two-dimensional
3D	three-dimensional
AIX	Advanced Interactive Executive (an implementation of the UNIX operating system)
AGL	Astronet Graphical Library
ARC	Automatic Ratio Control
ASCII	American Standard Code for Information Interchange
BMP	Mackintosh graphic format
C	high-level programming language
CASE	Computer Aided Software Engineering tools
CDF	Comma Delimited Format (file name extension/file type)
DEC	Digital Equipment Corporation
DCF	Two-dimensional Graphics File Format
FFT	Fast Fourier Transform
FORTRAN	Formula Translator (programming language)
Free BSD	Free Berkeley Software Distribution (UNIX)
GIF	Graphics Interchange Format
GIS	Geographic Information System
GNU	"GNU's Not UNIX" (Free Software Foundation operating system)
HDF	Hierarchical Data Format
HP-UX	Hewlett-Packard operating system
IDI	Image Display Interface
IDL	Interactive Data Language
I/O	input/output
IRIX	main operating system used by Silicon Graphics Workstations
JPEG	format for compressed graphics files (Joint Photographic Expert Group)
Linux	an implementation of the UNIX operating system
MCL	MIDAS Common Language
MIDAS	Munich Image Data Analysis System
NetCDF	Network Common Data Format
OS-routines	Operating System routines
RAW	a mode that allows a program to transfer bits directly to or from an I/O device without any processing, abstraction, or interpretation by the operating system
Solaris	Sun-UNIX-based user environment, including the UNIX operating system and an XII-based window system
Solaris x 86	Solaris implementation for personal computers
SPRING	Sistema de Processamento de Informações Geograficas (Remote Sensing Image Processing System)
TIFF	Tagged Image File Format
UNIX	AT & T Bell Laboratories operating system
VAX	Virtual Address Extended
VMS	Virtual Memory System (operating system on VAX computers)
Widget	window gadget (a combination of a graphic symbol and program code to perform a specific function in a graphical user interface (GUI)
WYSIWYG	"what you see is what you get"

INTRODUCTION

A. Background and objectives

1. The General Assembly, in its resolution 37/90, decided, on the recommendation[1] of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space that the United Nations Programme on Space Applications, should, *inter alia*, promote greater cooperation in space science and technology between developed and developing countries as well as among developing countries.

2. The Committee on the Peaceful Uses of Outer Space at its thirty-ninth session took note of the activities proposed for the United Nations Programme on Space Applications for 1997,[2] as recommended by the Scientific and Technical Subcommittee at its thirty-third session. Subsequently, in its resolution 51/123 of 13 December 1996, the General Assembly endorsed the activities of the Programme for 1997.

3. In response to General Assembly resolution 51/123 and in accordance with the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, the United Nations/European Space Agency/Committee on Space Research Workshop on Data Analysis Techniques was organized within the framework of the activities of the Programme for 1997, particularly for the benefit of developing countries.

4. The Workshop was organized jointly by the Office for Outer Space Affairs of the United Nations Secretariat, the European Space Agency (ESA), the Committee on Space Research of the International Council of Scientific Unions (ICSU), and the National Institute for Space Research (INPE) of Brazil.

5. The objective of the Workshop was to provide a forum for educators and scientists concerned with access, analysis and interpretation of data from Earth observation satellites. Such a forum would foster communication between developers and users with a wide range of expertise in the production and use of software packages to pursue data management in remote sensing, satellite meteorology and astronomy. Another objective of the Workshop was to provide participants with an expert knowledge of the tools available for access, analysis, and interpretation of data acquired by digital data acquisition systems for a variety of educational, scientific and development-oriented applications.

6. Basic and advanced principles and methods were presented in the Workshop and reinforced with practical examples from everyday data access, analysis and interpretation operations. The presentations and discussions focused on promoting understanding of the concepts involved through practical exercises. Participants brought problems from their own practical experience for discussion.

B. Organization and programme of the Workshop

7. The Workshop was held at the National Institute for Space Research (INPE), São José dos Campos, from 10 to 14 November 1997. Participants evaluated the advances that had taken place since the subject of data analysis techniques had been addressed by a United Nations workshop organized in conjunction with the XVIIth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS) at Washington, D.C. from 6 to 7 August 1992 (A/AC.105/545 and Corr.1).

8. The Workshop was attended by 50 space scientists from Argentina, Austria, Brazil, Chile, China, Ecuador, France, Germany, India, Indonesia, Lebanon, Nigeria, Paraguay, Slovakia, Sri Lanka, the Syrian Arab Republic, Thailand, the United States of America and Uruguay, and from Palestine. The United Nations and ESA provided financial support to defray the cost of air travel and living expenses of 17 participants from developing countries. Meeting facilities, equipment and local transportation were provided by INPE.

9. The programme of the Workshop had been developed jointly by the Office for Outer Space Affairs, INPE and the Committee on Space Research. The programme of the Workshop included presentations on:

(a) A review of basic concepts in data analysis techniques;

(b) The time and frequency domains;

(c) Time histories and time series analysis;

(d) Basic curve fitting;

(e) Yield point determination;

(f) Oscillating signal analysis;

(g) Spectral domain operations;

(h) Data filtering;

(i) Signal integration and differentiation;

(j) Transient data analysis;

(k) Continuous data analysis;

(l) Data averaging;

(m) Data compression;

(n) Neural networks and fuzzy logic in image processing;

(o) Neural networks for signal processing;

(p) Wavelets;

(q) Multidimensional signal processing;

(r) Applications of image processing and data analysis to all fields, including remote sensing, satellite meteorology, and astronomy.

10. Opening addresses were made by the representatives of the National Institute for Space Research of Brazil, the United Nations Office for Outer Space Affairs, and ESA.

11. The present report, which covers the background, objectives and organization of the Workshop and summaries selected presentations made at the Workshop, was prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. The participants reported on the knowledge acquired and the work conducted at the Workshop to the appropriate authorities of their Governments, universities, observatories and research institutions.

SOFTWARE SYSTEMS FOR IMAGE PROCESSING AND DATA ANALYSIS

A. Centres for space science and technology education

12. A major prerequisite for successful space science and technology applications in developing countries was the development of various essential indigenous capacities, particularly human resources, within each region. In recognition of that fact, the General Assembly, in its resolution 45/72, had endorsed the recommendation of the Working Group of the Whole of the Scientific and Technical Subcommittee (A/AC.105/456, annex II, para. 4 (n)), as endorsed by the Committee on the Peaceful Uses of Outer Space, that "the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries".

13. The Office for Outer Space Affairs, through the United Nations Programme on Space Applications, had translated that endorsement by the General Assembly into an initiative aimed at establishing regional centres for space science and technology education (affiliated to the United Nations) in developing countries. The concept behind those centres was based on the fundamental notion that it was vital for developing countries to have indigenous personnel trained in the use of space science and technology, particularly those applications relevant to their national development programmes, such as remote sensing, satellite meteorology and the use of geographic information systems, space communications and basic space science. Only then would the developing countries be able to contribute effectively to the solution of global, regional, and national environmental and resource management problems.

14. The Centre for Space Science and Technology Education for Asia and the Pacific (affiliated to the United Nations) had been established in India in November 1995. The Centre had its campus at the Indian Institute of Remote Sensing (IIRS), at Dehradun. The Centre used the infrastructure available at IIRS for conducting remote sensing and GIS courses; the Space Applications Centre, Ahmedabad, for courses on satellite communications and satellite meteorology; and the Physical Research Laboratory, Ahmedabad, for space sciences.

15. Brazil and Mexico had been selected as the host countries for the regional Centre for Space Science and Technology Education (affiliated to the United Nations) for the Latin America and the Caribbean region. The agreement establishing the Centre had been signed by Brazil and Mexico in March 1997 and the text of the agreement was being distributed to all Member States of the region for their concurrence.

16. Plans for the establishment of such centres, one in Western Asia and one each for the French-speaking and English-speaking regions of Africa, in Morocco and Nigeria respectively, were nearing completion.

B. Data management units of the centres

17. The initial programmes of each centre would focus on remote sensing and geographic information systems, meteorological satellite applications, satellite communications, and basic space science. Each centre would also have a data management unit (DMU), linked to relevant global data bases in order to meet the data needs at the centres. The functions of the DMUs would include data collection, key entry, programming, operations and maintenance of data files, programs, and hardware. The programme of the Workshop focused accordingly on data analysis techniques as part of computer software systems and languages.

C. Computer software systems and languages

18. In the 1970s until the mid-1980s, scientific computing had expanded to an extraordinary degree. The available technology had moved from the single campus computer to widely available minicomputers

(workstations) and the personal computer (PC). What was missing, however, was a language-neutral environment, in which scientific programming could be carried out in any available computer language. Since then, a number of programming languages had begun to dominate the field, and a growing minority of scientists were using Interactive Data Language (IDL), Mathematica and similar integrated total environments. Furthermore, programming languages like Fortran were gradually being upgraded and designed to produce codes for parallel processing on computers with multiple processors. Integrated total environments consisted of intrinsically higher-level programming languages. Eventually, IDL, Mathematica, and Fortran 90 (complemented by Numerical Recipes) had emerged as comparably high-level programming languages.

D. Interactive Data Language

19. IDL was a complete computing environment for the interactive analysis and visualization of data. It integrated a powerful, array-oriented language with numerous mathematical analysis and graphical display techniques. By programming in Fortran or C, using IDL, tasks that had required days or weeks of programming with traditional languages could be completed in hours. Users could explore data interactively using IDL commands and then create complete applications by writing IDL programs.

20. IDL had the following advantages:

(a) It was a complete, structured language that could be used both interactively and to create sophisticated functions, procedures and applications;

(b) Operators and functions worked on entire arrays (without using loops), simplifying interactive analysis and reducing programming time;

(c) Immediate compilation and execution of IDL commands provided instant feedback and "hands-on" interaction;

(d) Rapid 2D plotting, multi-dimensional plotting, volume visualization, image display, and animation made it possible to observe the results of computations immediately;

(e) Many numerical and statistical analysis routines—including Numerical Recipes routines—were provided for the analysis and simulation of data;

(f) The flexible input/output facilities of IDL made it possible to read any type of custom data format. Support was also provided for common image standards (including BMP, GIF and JPEG) and scientific data formats (CDF, HDF and NetCDF);

(g) IDL widgets could be used for the speedy creation of multi-platform graphical user interfaces to IDL programs;

(h) IDL programs ran the same way in all supported platforms (UNIX, VMS, Microsoft Windows, and Mackintosh systems) with little or no modification. The portability of applications made it possible to support easily a variety of computers;

(i) Existing Fortran and C routines could be dynamically linked to IDL to add specialized functionality. Alternatively, C and Fortran programs could call IDL routines as a subroutine library or display.

E. Geographic Information System and Remote Sensing Image Processing System

21. The Sistema de Processamento de Informacóes Geograficas (SPRING) was a state-of-the-art GIS and remote sensing image processing system, with an object-oriented data model that provided for the integration of raster and vector data representations in a single environment. It had been developed by INPE, with assistance from Brazil's Agricultural Research Agency (EMBRAPA), IBM Brazil, the Coordinating Commission for the System for Surveillance of the Amazon (CC/SIVAM) and the National Research and Development Agency (CNPQ). SPRING was being used for a number of important projects in Brazil, including the multi-temporal evaluation of deforestation in the Amazonia rain forest; ecological-economic zoning for Brazil; and the National soils data base.

22. The traditional data processing techniques supported by SPRING included the following:

(a) Image processing: registration, mosaicking, enhancement, filtering, IHS principal components transformations, arithmetical operations, maximum-likelihood pixel-based classifier;

(b) Digital terrain modelling: grid generation, contour plotting, slope/aspect maps, 3D visualization;

(c) Thematical and cadastral maps: digitizing, editing, topology generation, raster to and from vector conversion, mosaicking;

(d) Data base query and spatial presentation;

(e) Support for 14 cartographical projections;

(f) Import/export to ARC/INFO, DXF, ASCII, RAW and TIFF formats;

(g) WYSIWYG map production (with symbol library).

23. Among the innovative characteristic and techniques introduced by SPRING were the following:

(a) Menu-driven interface, presenting a unified environment for the geographical data types;

(b) Segmentation techniques and region-based classifiers (non-supervised and supervised);

(c) Restoration of Landsat and satellite pour l'observation de la Terre (Earth observation satellite) (SPOT) images;

(d) Mixture models for remote sensing imagery;

(e) Markovian techniques for post-classification;

(f) Radar image processing;

(g) Triangular grids generation with restrictions;

(h) Object-oriented Geographical Analysis Language.

24. In the interest of the widespread use and dissemination of remote sensing and GIS techniques for an ever-growing user community, SPRING had been made available as freeware software

(http://sputnik.dpi.inpe.br/spring). SPRING currently supported the following UNIX environments: AIX 3.2.5, HP-UX 9.0, IRIX 4.0, Linux 2.0, Solaris 2.5 and Solaris x 86 2.5. INPE was working to make a full English-language documented source code for SPRING available on the Internet, under the GNU General Public License, and on a version for FreeBSD, Windows 95 and Windows NT platforms.

F. Astronomical Data Analysis and Image Processing System

25. The Munich Data Analysis System (MIDAS) of the European Southern Observatory (ESO) was designed to allow easy integration of complex analysis algorithms, as well as greater flexibility in interactive use and in the creation of user-specific procedures from the basic building blocks. MIDAS was also available on the Internet (http://www.eso.org/research/data-man/data-proc/systems/esomidas/midas.html).

26. The first design proposal for MIDAS, made in the late 1980s, used ideas from the STARLINK project of the United Kingdom of Great Britain and Northern Ireland for the software interface definitions. The current version, which had become available in 1984, followed a similar philosophy in its application program interfaces but had been expanded to the new Standard Interfaces, which had a broader base.

27. The initial design of MIDAS was made on a DEC/VMS system in the early 1980s. In the late 1980s, however, with the acceptance of UNIX by the scientific community as a standard operating system and with the introduction of workstations, the system had been largely redesigned and currently ran on a wide variety of computers, with either DEC/VMS or one of the various implementations of UNIX as the operating system.

1. Design of MIDAS

28. In the design of MIDAS, a number of basic requirements had been taken into account in order to ensure that the system could evolve, namely:

(a) Modular design, which made it easy to adapt to different environments;

(b) Portability, to ensure that MIDAS could run on different computers;

(c) The adoption of standards, like the programming languages Fortran and C, and the X Window system. The use of standard programming languages enabled CASE tools to be used and made it simpler to shift to object-oriented coding;

(d) Easy programming through the provision of simple interface routines to access the data, and implementation of a flexible control language;

(e) Open design, which made it easy to add contributed software from other institutes.

2. Basic configurations and characteristics

29. The basic system was designed to work on a single computer with appropriate peripherals. It consisted of the following three parts: the monitor, the applications, and the interfaces. The MIDAS monitor included user interface, and routines for the administration of tasks and local variables. MIDAS was command driven. All the user interaction and the scheduling of processes to execute the commands was done through the monitor. The monitor had the following functions:

(a) To display on-line help with different levels of detail;

(b) To keep a log of all operations during a session;

(c) To serve as a command interpreter;

(d) To reprocess input strings to translate user defined symbols and to facilitate command numbering and buffering etc.;

(e) To execute applications on a subprocess.

30. MIDAS was a multiprocess system. In MIDAS, applications performed the actual operations on the data. They could be written in standard Fortran77, C, or the MIDAS control language. All communication must go through the monitor and was done through keywords and frame descriptors. The functions of the applications in MIDAS were divided into several levels of importance, the top level being the primary or core applications without which image-processing would be practically impossible. The core applications took care of:

(a) Image display, comprising all the usual functions expected from a mature image-processing system, such as displaying and retrieving data in full or split-screen mode, zoom and scroll, getting cursor values, modifying look-up tables, blinking etc. The kernel of the package was the Image Display Interfaces library (IDI);

(b) Graphics display, which provided the functionality needed for data presentation in graphical form, as well as interactive data reduction. The graphics package was device-independent, and based on the Astronet Graphic Library (AGL);

(c) General image processing, which included typical arithmetic operations like filtering, resampling, interpolation, rotation, extraction/insertion, FFT etc.;

(d) Table File System, which provided a complete set of functions for processing tabular data, including reading, writing, editing, searching, sorting, regression etc.;

(e) Fitting package, which afforded the necessary tools to fit non-linear functions and to model data distributions both in table and image format;

(f) Data I/O - to transfer the data from and to tape or disk.

31. The interfaces bound the applications to the monitor and defined the possible interaction with application and monitor. An additional level, the lowest, was used to interface MIDAS itself to the host operating system and was not to be used for application programs. MIDAS was based on three sets of general interfaces that allowed easy integration of application programs into MIDAS, namely: (a) the "standard interfaces" for general I/O and image access; (b) the "table interfaces" for access to table structures; and (c) the "graphics interfaces" for easy inclusion of graphical representation of the MIDAS data structures. To provide a portable system, a layer of OS-routines had been used to shield MIDAS from the local operating system.

MIDAS Command Language

32. The MIDAS Command Language, (MCL), provided the tools for constructing complex command procedures from existing commands. Since all application programs got their parameters through a set of standard interfaces, it was very simple to string commands together, each using results from the previous command. In fact, except for the system commands, all MIDAS commands were MCL procedures themselves. In general, MCL provided the basic features of a programming language, such as definition of parameters,

looping, conditional statements and branching, global and local variables, procedure calls (also recurrent) with parameters, and built-in functions. MCL was an interpreted language, meaning that the definition of local variables could be done anywhere in a procedure and that no compilation and linking steps were required before executing a MCL procedure.

33. Data items in MIDAS could be divided into several groups:

(a) Frames - data sets that had a uniform sampling, for example images or spectra. Up to 16 dimensions could be supported; most applications, however, were limited to two dimensions;

(b) Tables - collections of heterogeneous data organized in columns and rows;

(c) Descriptors - variables related to the general database, e.g. frames and tables. They were used to describe the data in detail;

(d) Keywords - variables relating to processes or sessions. They were similar to descriptors and were mainly used to transfer information between, and to control, tasks;

(e) Catalogues, containing lists of either images, tables or fit files for the purpose of grouping data together.

Notes

[1]See *Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-21 August 1982* (A/CONF.101/10 and Corr.1 and 2), Part One, sect. III.F, para. 430.

[2]*Official Records of the General Assembly, Fifty-first Session, Supplement No. 20* (A/51/20), sect. II.B, para. 39.